# EFFECT OF CEMENT – AGGREGATE RATIO WITH AN ALKALINE ADDITION (NaOH) ON THE MECHANICAL PROPERTIES OF COMPRESSED STABILISED EARTH CUBES

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# ABSTRACT

Compressed stabilized earth block (CSEB) is one of the new materials utilized as a part of Industrialized Building System (IBS). The usage of CSEB in development industry can be new construction material which is more efficient that can save overall construction period and cost. Nowadays, CSEB are one of the first choices as building materials that being used in the construction. There are so many factors that need to be considered in making stronger compressed stabilised earth cubes especially in term of its strength and durability that to be applied in building construction. The presence of an alkaline solution, optimum mix proportion (cement, soil and sand) and curing method will affect the cubes strength. The purposes for this research are to determine the compressive strength, abrasion and water absorption of the cubes by using different proportion ratios of aggregates added to the cement and also to determine the effect of alkaline to the compressive strength of the cubes. Three sets of cube which are constant in cement-aggregates ratio, 1:8 but different in soil-sand ratio (1:2:6, 1:3:5 and 1:4:4) were carried out. Each set will include an alkaline solution in different concentration which are 1, 2 and 3molarity. The only curing method used is air curing for 28 days. Cubes mechanical properties can be determine by compression test, abrasion test and water absorption test. The highest compressive strength result achieved for control is in 1:4:4 mix proportion with a value of 4.599MPa for 28 days curing age and for the presence of an alkaline solution the highest strength is in 1:4:4 mix proportion with 1mol of concentration, 4.555MPa. All cubes strength did not achieved 5.2MPa at 28 days aged of curing to satisfy the minimum permissible average compressive strength for the cubes. Water absorption for 1:3:5 cubes mix proportion shows lowest percentage compare to the others. The cubes also have their own durability and would be able withstand in harsh environment since the average percentage losses are very small which is less than 1.5%.

# ABSTRAK

Kestabilan Mampatan blok (CSEB) merupakan salah satu bahan baru yang digunakan sebagai sebahagian daripada sistem pembinaan industri (IBS). Penggunaan CSEB dalam industri boleh menjadi bahan pembinaan yang baru yang lebih efisyen yang boleh menjimatkan kos dan tempoh keseluruhan pembinaan. Terdapat banyak faktor yang perlu dipertimbang dalam membuat kiub yang lebih kukuh terutamanya dari segi kekuatan dan ketahanan kiub yang digunakan dalam pembinaan bangunan. Kehadiran larutan alkali, nisbah campuran yang optimum (simen, tanah dan pasir) dan kaedah pengawetan akan memberi kesan kepada kekuatan kiub. Kajian ini dilaksanakan adalah untuk menentukan kekuatan, lelasan dan penyerapan air kiub dengan menggunakan perkadaran nisbah yang berbeza bagi tanah dan pasir yang ditambah kepada simen dan juga untuk menentukan kesan alkali untuk kekuatan mampatan kiub. Tiga set kiub dalam nisbah simen agregat yang sama iaitu 1:8 tetapi berbeza dalam nisbah tanah-pasir (1:2:6, 1:3:5 dan 1:4:4) telah dijalankan. Setiap set akan diuji dengan larutan alkali dalam kepekatan yang berbeza iaitu 1, 2 dan 3molariti. Satu-satunya kaedah pengawetan yang digunakan adalah pengawetan udara selama 28 hari. Sifat mekanik bongkah boleh ditentukan dengan ujian mampatan, ujian lelasan dan ujian penyerapan air. Hasil kekuatan tertinggi mampatan dicapai untuk kawalan adalah dalam nisbah 1:4:4 yang bernilai 4.599MPa selama 28 hari pengawetan dan bagi kehadiran larutan alkali kekuatan yang paling tinggi adalah dalam nisbah 1:4:4 dengan 1mol kepekatan alkali, 4.555MPa. Semua kiub tidak mencapai kekuatan 5.2MPa pada 28 hari pengawetan yang perlu dicapai oleh kiub. Penyerapan air untuk 1:3:5 nisbah campuran kiub menunjukkan peratusan terendah berbanding dengan yang lain. Kiub juga mempunyai ketahanan mereka sendiri dan akan dapat bertahan dalam persekitaran yang keras apabila ia menunjukkan purata peratusan yang sangat kecil iaitu kurang daripada 1.5%.

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# CHAPTER 1

# INTRODUCTION

## 1.1 Background of Study

The provision of housing is a test confronted by all nations around the globe, particularly in developing nation like Malaysia. With the increment of development materials expenses as for example, cement, steel and timber; builders are not always have a desire to construct a house on a tight plan. Several possible solutions has been investigated to reach the goal as to fulfil client demand by using minimal effort building material and cost but still can produce affordable and good quality of housing.

Compressed Stabilised Earth Block (CSEB) is one of the new development materials utilizing pre-assembled parts that can interlock to each other and it's improvise from ordinary steps that do not require mortar in bricklaying work. The quantity of cement that reacts as stabilised agent and the laterite soil are needed as to build quality of laterite CSEB. The common sense utilization of cubes method in development will minimise the total cost and time spend as there will be no mortar include in bricklaying work. Furthermore, it does not need talented and experienced worker (Nasly et al, 2009). The utilization of laterite CSEB is a perfect solution due to decreasing the materials usage and development cost (Adeyeye, 2012).

From the previous study that made by Ahmad Rashdan bin Mansor in 2014, two types of curing method were conducted which are left in sun for set 1 and left in shade for set 2. Three sets of block were prepared with the ratio used are different between each other, 1:2:6, 1:1:6, 1:0.5:6 (cement, laterite soil, sand) with the addition of alkaline solution of 1 molarity and 2 molarity of 1:2:6 mixture. Besides that, the laterite soils were obtained from nearby site location at University Malaysia Pahang, Kuantan.

At all stage of 7days, 14days and 28days of ages, curing set 1which is left in sun was stronger than curing set 2. The maximum compressive strength that was recorded for ratio curing set 1 at 28 days was 3.96Mpa. Furthermore, the ratio of 1:1:6 was stronger than ratio 1:0.5:6 and 1:2:6 at all stage of ages ratio. The highest compressive strength was in ratio 1:1:6 at 28 days of age recorded was 5.63Mpa. Moreover, the highest compressive strength is in 2 molarity alkaline solutions on 28 days which is 5.4Mpa but slightly higher than 2 molarity alkaline solutions, 5.06MPa.

From the previous study that made by Habsullah Ali b Abd Rahim and Muhamad Zulkarnain b Zainal in 2014, the highest compressive strength of interlocking blocks were achieved 7.01MPa in 7 days of aged of curing when it was dried in sun.

This study will explore more on physical and mechanical properties of the cubes by using different ratio of aggregates with a constant amount of cement with the presence of an alkaline solution (NaOH).

## 1.2 Problem Statement

Cement and clay substances in cubes had a potential in determining the compressive strength, however the ideal ratio between cement-aggregates is not decided yet for minimum permissible average compressive strength for the cubes which is 5.2MPa according to an American Standard Testing Machine (ASTM) C-129 at the 28 days aged of curing. Optimum mixed proportions will give high quality with a maximum strength of a cube.

The standard compression strength that needs to achieve by the cubes is 5.2 N/mm2 for load bearing wall. Based on previous research, the optimum mix proportion had been obtained which is 1:2:6 and the strength of cubes will increase if the concentration of an alkaline solution increases. The expected result will be the cubes by using laterite soil with the present of alkaline can achieved the minimum permissible average compressive strength for the cubes is 5.2MPa at 28 days aged of curing.

## 1.3 Objective of Study

The main objective for this research is to determine the mechanical properties of cubes in the presence of an alkaline solution, Sodium hydroxide ($NaOH$) 1, 2 and 3molarity. Other sub objectives that may follow this research are:

i. To determine the compressive strength, abrasion and water absorption of cubes.
ii. To determine optimum mix proportion of cement ratio between laterite soil and sand.
iii. To determine the effect of alkaline solution to cubes in different soil-sand ratio with a constant amount of cement.

## 1.4 Scope of Study

The scopes of study are focus on:

i. Testing the properties of soil with mineralogy test, hydrometer test, Atterberg limit test and sieve analysis.
ii. Testing the properties of cubes with compression test, abrasion and water absorption.
iii. Testing the cubes strength with the presence of an alkaline solution (1,2 and 3 molarity)
iv. Produce the cubes using same cement-aggregates ratios (1:8) but varies in laterite soil to sand ratio.

## 1.5 Significance of Study

This research is to determine the cubes optimum mix design by improving its mechanical properties in the different concentration of an alkaline solution. Cubes mechanical properties include its compressive strength, durability and water absorption. This research will study the effect of an alkaline solution towards the cubes strength, durability, water absorption and the advantages by using an alkaline solution in the making of cubes. In the end of this research, the cubes optimum mix proportion and the effect of an alkaline solution to the cubes will be known.

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 INTRODUCTION

In general, some of laterites soils have a chemical reaction when it mixed with an alkaline solution by depending on the amount of clay content thus producing hard and durable building materials such as stabilized earth blocks. The laterite soils have a tendency to harden in the presence of on air moisture content, which is the reason why blocks have traditionally been widely used in India and it's allowed to harden and then used for masonry wall construction.

## 2.2 LATERITE SOIL

The regular meaning of induration is a state in which the consistency of the medium is not influenced by humidity. Laterites very good material to structure yet can be diminished to some structural elements such as the indurated elements that form coherent skeleton and cement pre-existing materials. Furthermore, the level of laterite soil hardness ranges is basically from items that are unconsolidated to the hardest blocks which can be broken by using a hammer. The laterite soil hardness increase as the iron substance increase; minimum hydrated will give greater laterites value (Maignien, 1966).

Laterites are varying in colour, yet there are normally come in brightly colour. The shades are most as often as possible experienced are pink, orange, red and brown. Laterites owe their colour to iron oxides in different conditions of hydration. The physical properties of lateritic soil depend on mineralogical composition and molecule size distribution of the soil. One of the primary focal points of lateritic material is that it doesn't promptly swell with water. This makes it good for pressing material especially when it is not too sandy (Maignien, 1966).

## 2.3 BENEFITS AND LATERITIC MATERIAL IMPLEMENTATION

Lateritic material helps in decreasing quantity of cement utilized as a part of worldwide building construction. The decreasing in cement utilization through the utilization of environmental friendly building materials such as CSEB is a perfect approach to secure our surroundings through the lessening of energy consumption and CO2 emanations. In addition, the decision by using laterite materials is majorly because of financial factors. Based on Figure 2.1 below, there are some examples on how the laterite materials are being used around the world (Patrick, 2011).

**Figure 2.1:** Implementation of compressed earth block (Lemougna, 2011)

## 2.4 ALKALINE ACTIVATION

Alkaline cements are new binders, as an option to traditional Portland cements, acquired through the alkaline activation of varies industrial by-products. These new building materials are describe by its extraordinary mechanical performance, low energy cost and low pollutant gas emissions (CO2, SO2 etc.) produces during the manufacturing process of ordinary Portland cement (OPC). Furthermore, the presence of alkaline solution in the cement mixture can produce earlier and higher mechanical strengths (they can reach 100MPa at 28 days). Besides that, it's also have lower hydration heat and stronger resistance to chemical attack. The only disadvantage that can be described is its high shrinkage rate with formation of micro cracking (Wang et al., 1994).

The alkaline activation of materials is a substance reaction and transformation that gives a quick change of some particular structures, partial or totally amorphous and/or meta-stables, well-compacted and cementitious composites. Most of the environmental impact of the alkaline activation technique remains in the production of the alkaline activator compounds, namely sodium hydroxide and sodium silicate (Provis, 2009). In general, the alkaline activation was indicating to gives incredible results with respect to the changes in mechanical properties of CEBs manufactured. In other word, it can give a lot of advantages due to environmental impact and cost.

Geopolymers that had been conducted with a 14 M solution of NaOH gave a higher resistance to compression test than the samples conducted with a 8 M solution of NaOH, without comparing the curing temperature and age (Hardjito & Rangan, 2005). Moreover, the NaOH concentration solution plays an important factor in the strength of alkali activated fly ash-based geopolymers.

It has been observed that through chemical polymerisation which is mineral polymerization method, minerals such as clay could be hardened and changed into helpful construction materials (Ingles, 1970). All these mineral polymers are produced at minimum temperature by utilising minimal energy input. In this process, the aluminosilicate kaolinite responds with alkali at low temperatures and polycondenses into hydroxysodalite, which is a stable and hard material. Thus, mineral polymers and alkali-activated poly-aluminosilicates have been gradually gaining the consideration of the world as they are getting to be potential progressive materials (Patfoort & Wastiels, 1989). Several factors that can influence the overall compressive strength which are:

**a) Variation of Sodium hydroxide**

In increasing the amount of Sodium hydroxide (NaOH) will increase the total amount of compressive strength of all cylinder specimens with 50mm height and 25 diameter:

S1: dried cylinder specimens

S2: immersed cylinder specimens

S3: cycled wet cylinder specimens

S4: dried cycled cylinder specimens

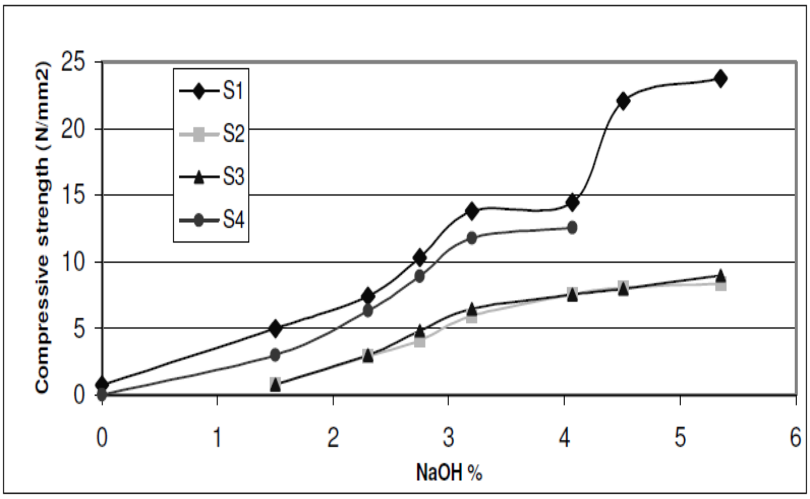


**Figure 2.2:** Compressive strength as a function of percentage NaOH (Alshaaer, 2000).

**b) Variation of water content**

The specimen compressive strength can be increase when the water content is closer to plasticity limit of the clay (Alshaaer, 2000).

### c) Soil Aggregates

The decreasing in size of the clay aggregates will increase the compressive strength. Basically, crushing soil sample into very small aggregates (less than 106 μm) has been demonstrated successful in order to achieve a solid construction material and provide larger surface reaction between the the soil and the NaOH solution. This reaction produces stronger network polymer, which ties the grains of the material together (Alshaaer, 2000).

### d) Additional treatment to improve the compression strength

The cylinder specimen that being cured in 80 C, and afterward were immersed in concentrated NaOH solution (± 5 M) will give a better compressive strength result compared to the normal treatment. Figure 2.3 shows the relation between duration of heating and specimen strength.

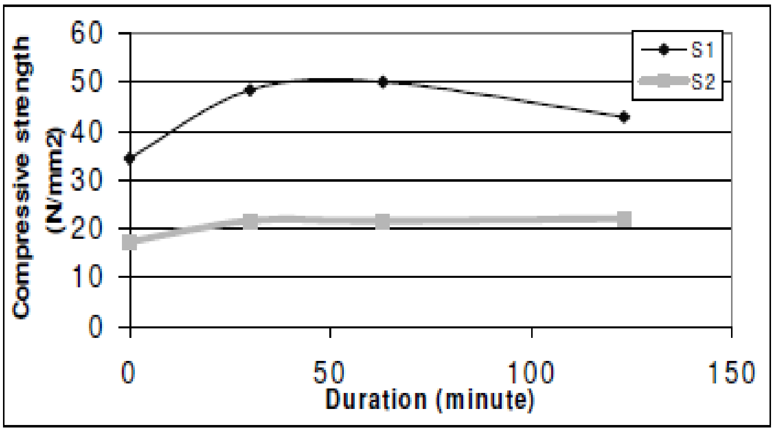


**Figure 2.3:** Variation of compressive strength with heating duration (Alshaaer, 2000).

Moreover, by referring the figure 2.4, heating the NaOH solution containing the specimens at 80 C around 50 minutes will change the NaOH density and shows a large increment in compressive strength with good stability under dry and wet conditions. Optimizing the heating time is essential in improving the quality and stability of the material.

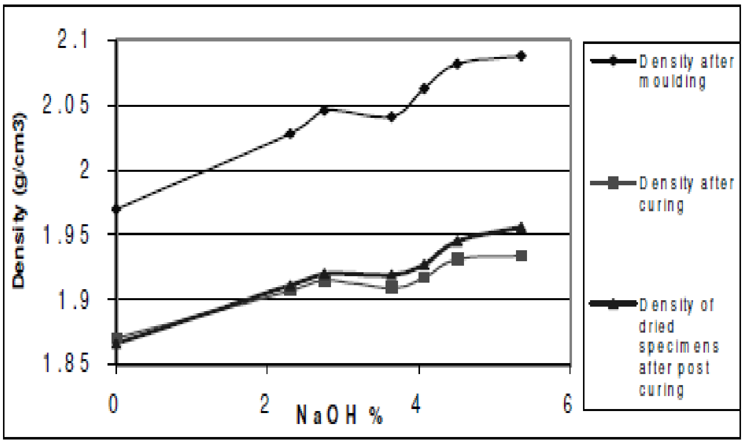


**Figure 2.4:** Variation of density with percentage NaOH (Alshaaer, 2000).

The sand/clay ratio should be optimized, as the mechanical and physical properties of the material depend generally on this proportion. In addition to that, use small amount of NaOH solution to avoid alkali/salt residual in the material and for financial reasons. Moreover, the density of alkali solution will be increase with increasing the amount of NaOH content or by using water close to the plasticity limit of the clay. In term of compressive strength, it will be decrease if the amount/percentage of NaOH in the specimen increases up above the optimum value because of the increasing the NaOH residual in the structure of the mineral polymers. The remaining NaOH could change to salts by absorption CO2 from the air, thus decreasing the strength and stability of the material (Alshaaer, 2000).

## 2.5 COMPRESSIVE STRENGTH

The reason for performing the compressive strength test is to determine the load-bearing limits of the cubes. The block compressive strength relies on upon different factors such as materials utilized, moisture content, curing period and curing method.

From previous research that had been done (Rashdan, 2014), two types of curing method were conducted which are left in sun for set 1 and left in shade for set 2. Three sets of block were prepared with the ratio used are different between each other, 1:2:6, 1:1:6, 1:0.5:6 (cement, laterite soil, sand) with the addition of alkaline solution of 1 molarity and 2 molarity of 1:2:6 mixture. At all stage of 7days, 14days and 28days of ages, curing set 1which is left in sun was stronger than curing set 2. The maximum compressive strength that was recorded for ratio curing set 1 at 28 days was 3.96Mpa. Furthermore, the ratio of 1:1:6 was stronger than ratio 1:0.5:6 and 1:2:6 at all stage of ages ratio. The highest compressive strength was in ratio 1:1:6 at 28 days of age recorded was 5.63Mpa. Moreover, the highest compressive strength is in 2 molarity alkaline solutions on 28 days which is 5.4MPa but slightly higher than 2 molarity alkaline solutions, 5.06MPa. The highest compressive strength of interlocking blocks were achieved 7.01MPa in 7 days of aged of curing when it was dried in sun (Zulkarnain, 2014).

The average compressive strength for the compressed stabilised earth cubes which is 3.5MPa according to an American Standard Testing Machine (ASTM) C-129 at the 28 days aged of compressive strength. According to the Malaysia Standard MS 7.6: 1972 / British Standard BS 3921: 1985, for General Brick Specifications, the average compressive strength for Load Bearing Brick Class 1 is 7.0 MPa.